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RESEARCH MEMORANDUM

for the

Signal Corps, U. S. Army

CALIBRATION OF INSTRUMENTS FOR MEASURING WIND VELOCITY AND DIRECTION

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

Signal Corps wind equipment AN/GMQ-1 consisting of a 3-cup anemometer and wind vane was calibrated for wind velocities from 1 to 200 miles per hour. Cup-shaft failure prevented calibration at higher wind velocities. The action of the wind vane was checked and found to have very poor directional accuracy below a velocity of 8 miles per hour. After shaft failure was reported to the Signal Corps, the cup rotors were redesigned by strengthening the shafts for better operation at high velocities.

The anemometer with the redesigned cup rotors was recalibrated, but cup-shaft failure occurred again at a wind velocity of approximately 220 miles per hour. In the course of this calibration two standard generators were checked for signal output variation, and a wind-speed meter was calibrated for use with each of the redesigned cup rotors.

The variation of pressure coefficient with air-flow direction at four orifices on a disk-shaped pitot head was obtained for wind velocities of 37.7, 53.6, and 98.9 miles per hour. A pitot-static tube mounted in the nose of a vane was calibrated up to a dynamic pressure of 155 pounds per square foot, or approximately 256 miles per hour.

INTRODUCTION

At the request of the Signal Corps, U. S. Army, instruments for determining wind velocity and direction were tested in two of the Langley wind tunnels. The primary purposes of the investigation were to get accurate calibrations of the instruments and to determine the ability of one of the devices to operate satisfactorily at speeds greater than

heretofore required. A structural failure of one of the instruments was experienced and this instrument was retested after slight changes had been made to strengthen it.

INSTRUMENTS AND APPARATUS

The wind-measuring equipment, furnished by the Signal Corps, U. S. Army, consisted of a 3-cup anemometer and wind-vane assembly (fig. 1) designated "Wind Equipment AN/GMQ-1, Wind Transmitter ML-203," a disk-shaped pitot head (fig. 2), and a pitot-static tube mounted on a vane (fig. 3).

The "Wind Equipment AN/GMQ-1" was tested at two different times with some slight differences in the equipment. As originally tested the equipment included three hub-shaft-cup assemblies, designated new cup number 1, new cup nummber 2, and old cup. The rotational speed of the cup assembly was determined from the output of an alternating-current generator driven by the cup assembly and connected to a frequency-measuring instrument. During the first series of calibrations it was found that the anemometer shafts connecting the cups to the hub were not strong enough to withstand the loads developed at high airspeed. After making a change in shaft diameter, the Signal Corps requested that additional calibrations be made. For these additional tests the equipment included three redesigned hub-shaft-cup assemblies designated number 1, number 2, and number 3, and two generators marked xx and xxx. The cups of assemblies numbers 2 and 3 were very similar, but the cups of assembly number 1 had less flange projecting at the rim. The assembly designated herein as cup rotor number 1 modified was number 1 with one of its cups replaced by a cup from number 2. The leads from the generator, two-wire no. 16 electrical cords 23 feet long, were connected to a wind-speed meter furnished by the Signal Corps, and 2 feet of the same leads were connected between the wind-speed meter and the frequency-measuring instrument. The wind-speed meter, with a scale range of 0 to 150 miles per hour, had been modified for use with wind velocities up to 220 miles per hour by providing a reduced sensitivity on an extended-scale setting.

The disk-shaped pitot head was approximately 6 inches in diameter and 1/4 inch thick with four orifices equally spaced around the rim. Flexible pressure tubes connected the orifices to a manometer. The pitot head was mounted to the ceiling turntable of the tunnel so as to allow rotational positioning of the orifices.

The vane-mounted pitot-static tube, as received for testing, was found to have air leaks in several joints and a poor seal in the pressure pickup ring that was used in order that the tube-vane assembly would be free to aline itself with the wind direction. Before testing, all leaks except that provided for water drainage were sealed, and the pressure pickup ring was bypassed with flexible tubing.

COEFFICIENTS AND SYMBOLS

q	dynamic pressure of air stream, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
q_i	impact pressure of air stream as obtained with pitot-static tube, pounds per square foot
ρ	mass density of air, slugs per cubic foot
V	velocity, feet per second
S	pressure coefficient $\left(\frac{H - p}{q}\right)$
H	total pressure in tunnel, pounds per square foot
p	pitot head orifice pressure, pounds per square foot

TEST TECHNIQUE

Calibrating the 3-cup anemometer and checking the accuracy of the wind vane for wind velocities below 25 miles per hour were performed in the Langley gust tunnel. The wind velocity was determined by a pitot-static tube and a hot-wire anemometer and the agreement between the results of the two methods was good. Anemometer calibrations above 25 miles per hour and calibrations of the disk-shaped pitot head and the pitot-static tube were made in the Langley 300 MPH 7- by 10-foot tunnel. The redesigned rotor cups were not tested below a velocity of 50 miles per hour.

The disk-shaped pitot head was mounted to the turntable in the ceiling of the tunnel. The difference between each orifice pressure and total pressure was measured by a manometer. Readings were taken at predetermined angular increments as the pitot head was rotated 90° in a clockwise direction when viewed from the ceiling of the tunnel. Data were obtained at wind velocities of 37.7, 53.6, and 98.9 miles per hour. Investigation of the tunnel air flow indicated that at the position the pitot head was located the air-flow angle was 0.4° in the direction from floor to ceiling. Data at a wind velocity of 37.7 miles per hour were also obtained with the axis of the north-south orifices of the pitot head inclined an additional 5° to the tunnel ceiling.

The impact pressure indicated by the pitot-static tube mounted on a vane was obtained by connecting pressure leads directly to the pitot-static tube thereby bypassing the pressure pickup ring which had leaks.

DISCUSSION

The calibration of the 3-cup anemometer with the original cup assemblies is given in figure 4. The rotational speed of the cups varied linearly with wind velocity between 10 and 100 miles per hour. There was little difference among the different cup assemblies in variation of rotational speed with wind velocity. While attempting to reach a velocity of 220 miles per hour, the shaft of one cup of new cup assembly number 1 failed at the juncture of the shaft and hub. The unbalance caused by the loss of one cup produced an appreciable vibration of the whole assembly. Examination of the cup shafts showed that two of the shafts were bent in the direction of rotation and the other one was bent opposite to the direction of rotation. Previously, the cup assembly had been run successfully at 60 rps in a vacuum by Flight Instrument Branch to test the ability of the cups to withstand the centrifugal forces.

The drag of the complete anemometer assembly with new cup number 1, and the drag with the cup assembly and generator removed are given in figure 5. The wind vane was found to have poor directional accuracy below 8 miles per hour.

The results of the calibration of the anemometer with redesigned cup rotors are given in figure 6. The variation of rotational speed with wind velocity is linear throughout the velocity range investigated. In making the calibration with redesigned cup rotor number 1, the wind velocity was increased to 222 miles per hour and the data for that point recorded, but as the wind velocity was being reduced the shaft of one cup broke at the point where the shaft was drilled for the inner pin that fastened the cup to the shaft. All subsequent calibrations were limited to a maximum wind velocity of approximately 200 miles per hour. The rotational speed of cup rotor number 1 was about 6.5 percent greater than the speed of the other two rotor cups. This percentage was decreased approximately one-third when the broken shaft and cup of cup rotor number 1 were replaced by a shaft and cup of cup rotor number 2. The greater speed of cup rotor number 1 may be accounted for by the fact that the cups had less flange at the rim, thereby reducing the counterrotational force on the cups as they moved upstream against the wind. Flexibility of the cup shafts before they were redesigned probably accounts for some of the loss in rotational speed at high wind velocities indicated on figure 4.

Figures 6 and 7 indicate that no measurable difference was found between the two generators used in conjunction with the redesigned cup rotors. The two low points on figure 7, though both recorded with generator xxx, are probably errors in reading the wind-speed meter since no such errors occur in the readings on the 150 miles per hour scale.

The calibration of the wind-speed meter as a function of wind velocity in operation with the different redesigned cup rotors, presented in figure 8, has a nearly linear variation for all combinations investigated.

The pressure data obtained with the disk-shaped pitot head are presented in figures 9 and 10. There was apparently little variation in pressure coefficient for any angular position of an orifice between 90° and 270° except between 150° to 220° where the orifice was directly behind the tubular supporting strut of the pitot head. The discontinuity of the curves where two orifice positions coincide (fig. 9) is accentuated by inclining the north-south axis of the disk an additional 5° to the tunnel ceiling (fig. 10). The inclination of 0.4° was introduced into the data by the air-stream misalinement with the tunnel ceiling.

Figure 11 gives the relation between the impact pressure indicated by the pitot-static tube mounted on a vane and the true dynamic pressure of the air stream. The variation is linear and may be expressed by the relation $q = 1.079q_i$ where q is the true dynamic pressure and q_i is the impact pressure measured with the pitot-static tube.

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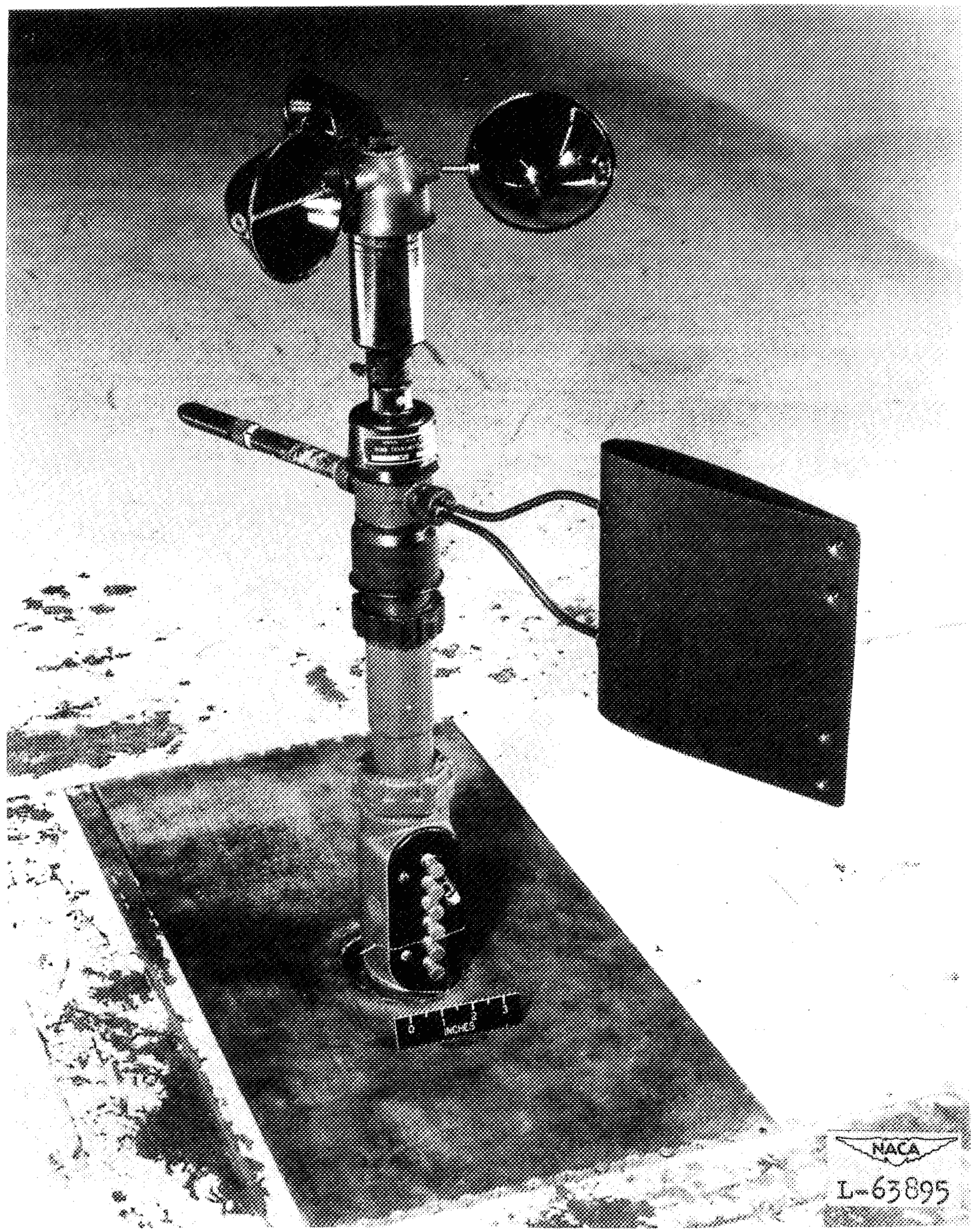

Figure 1.- Anemometer mounted on tunnel floor.

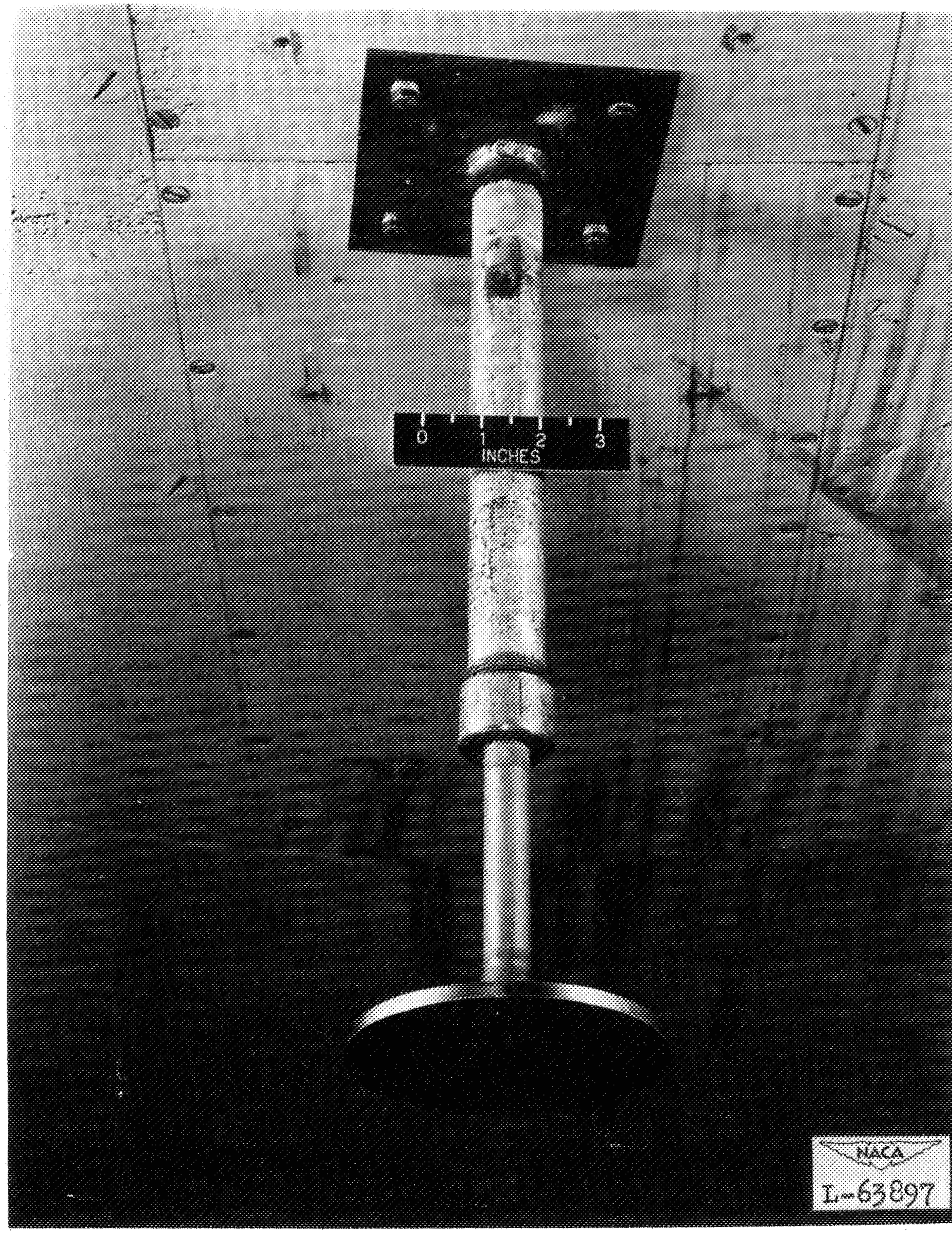

Figure 2.- Disk-shaped pitot head mounted on tunnel ceiling.

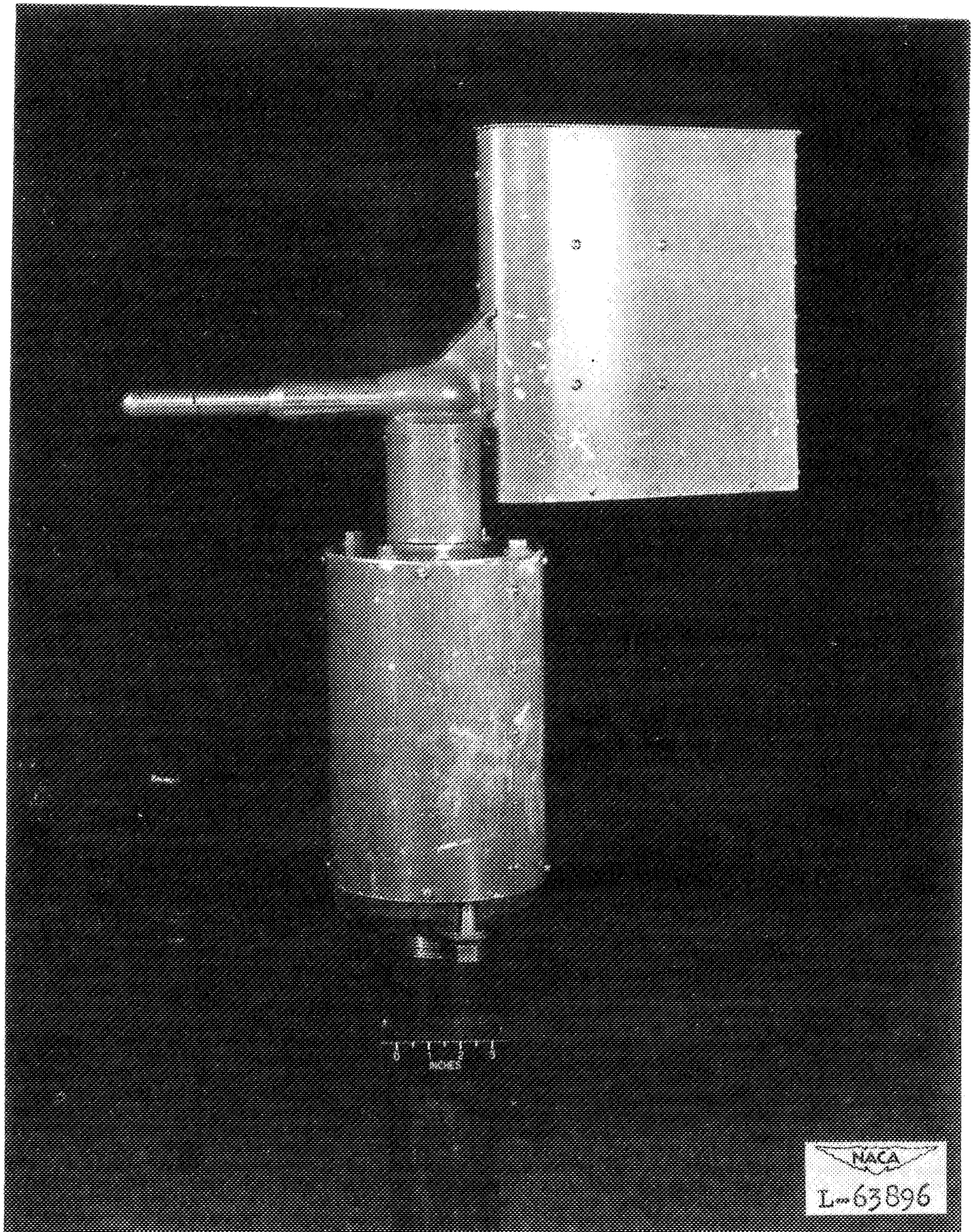

Figure 3.- Pitot-static tube vane assembly mounted on tunnel floor.

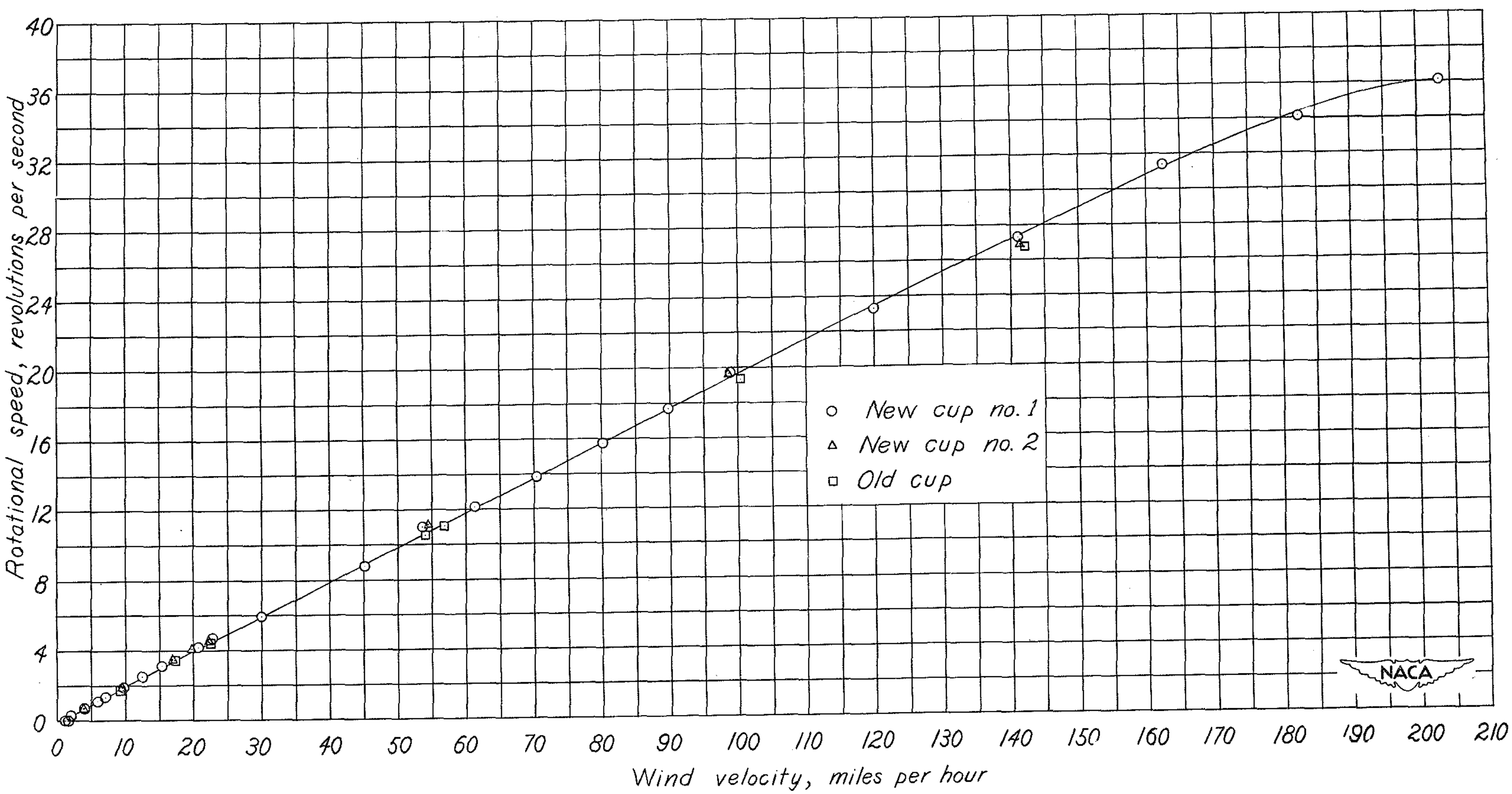

Figure 4.- Variation of the rotational speed of the cup rotors of the anemometer with wind velocity for three sets of cup assemblies.

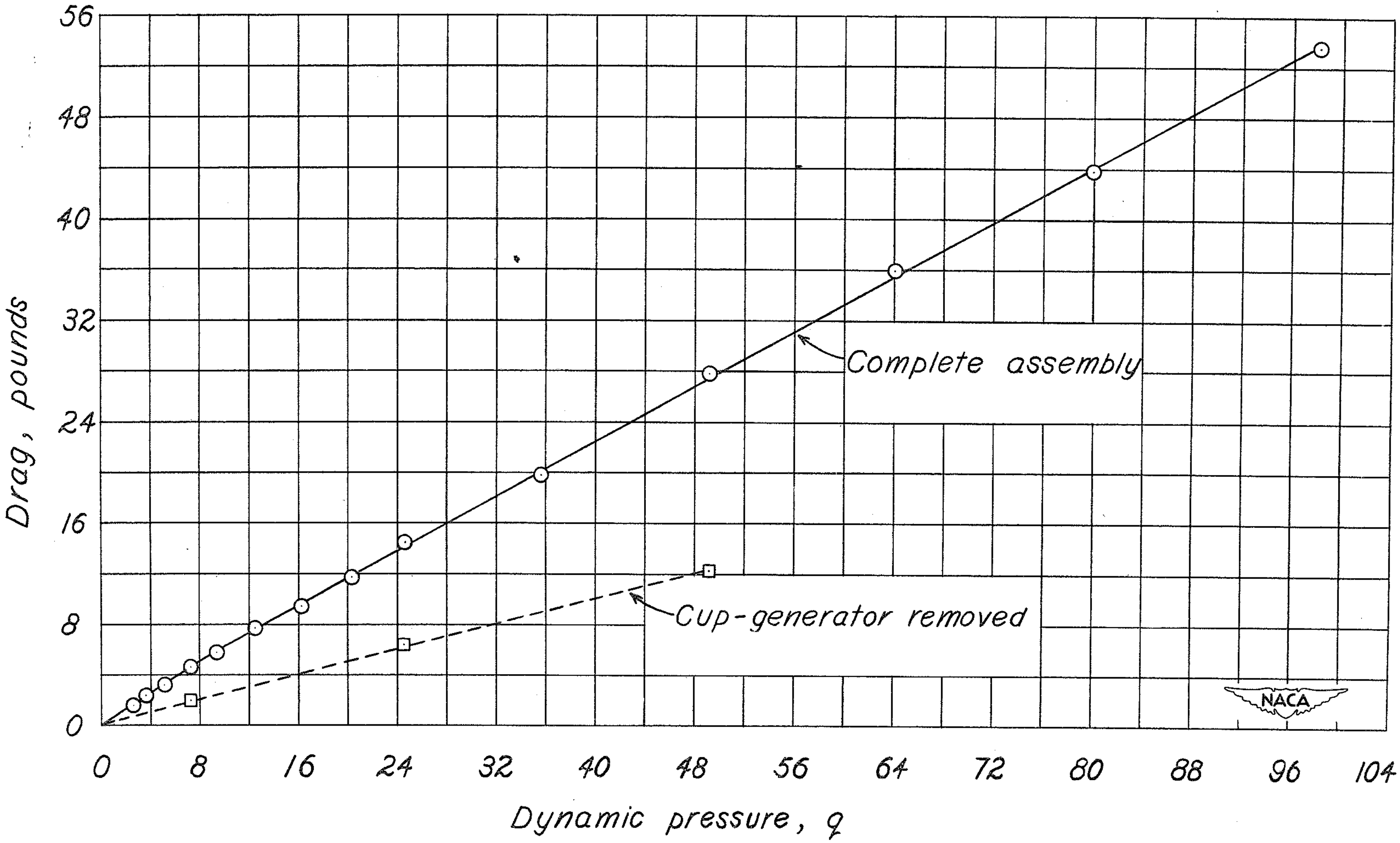

Figure 5.- Variation of drag with dynamic pressure for the anemometer assembly with new cup no. 1 and with the cup-generator removed.

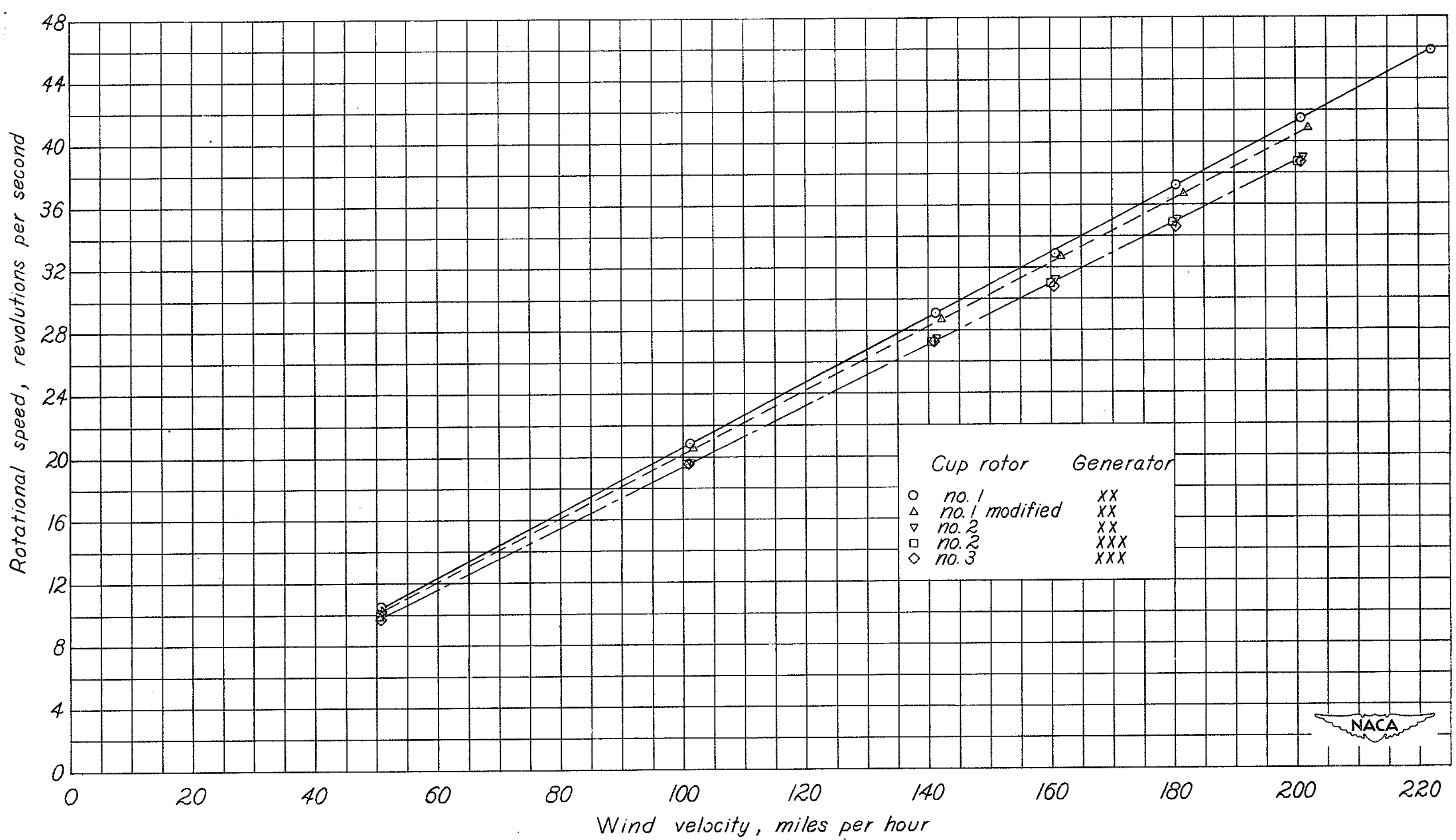

Figure 6.- Variation of the rotational speed of the redesigned cup rotors of the anemometer with wind velocity for various cup rotors and generators.

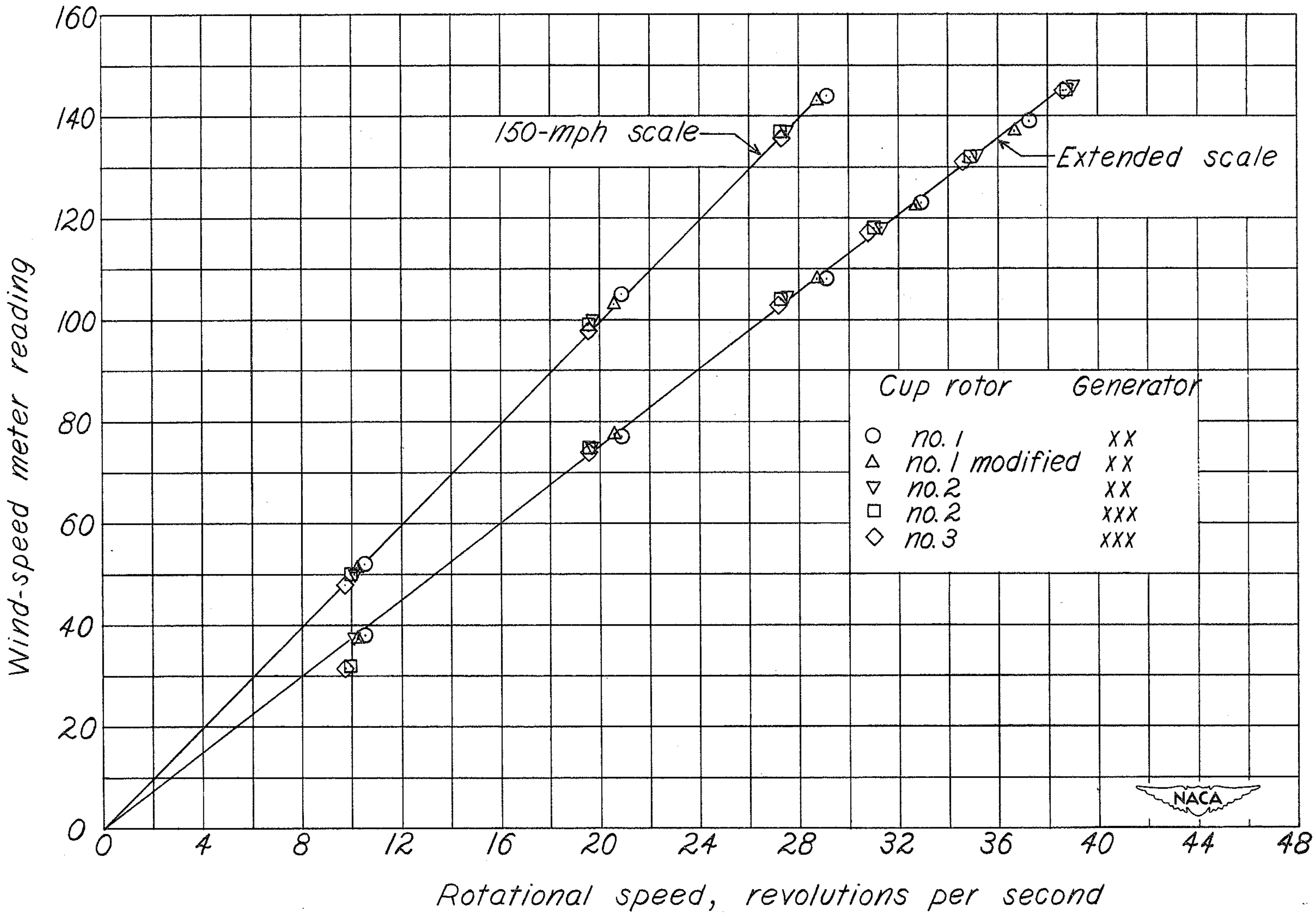

Figure 7.- Variation of wind-speed meter reading with rotational speed of the redesigned cup rotors.

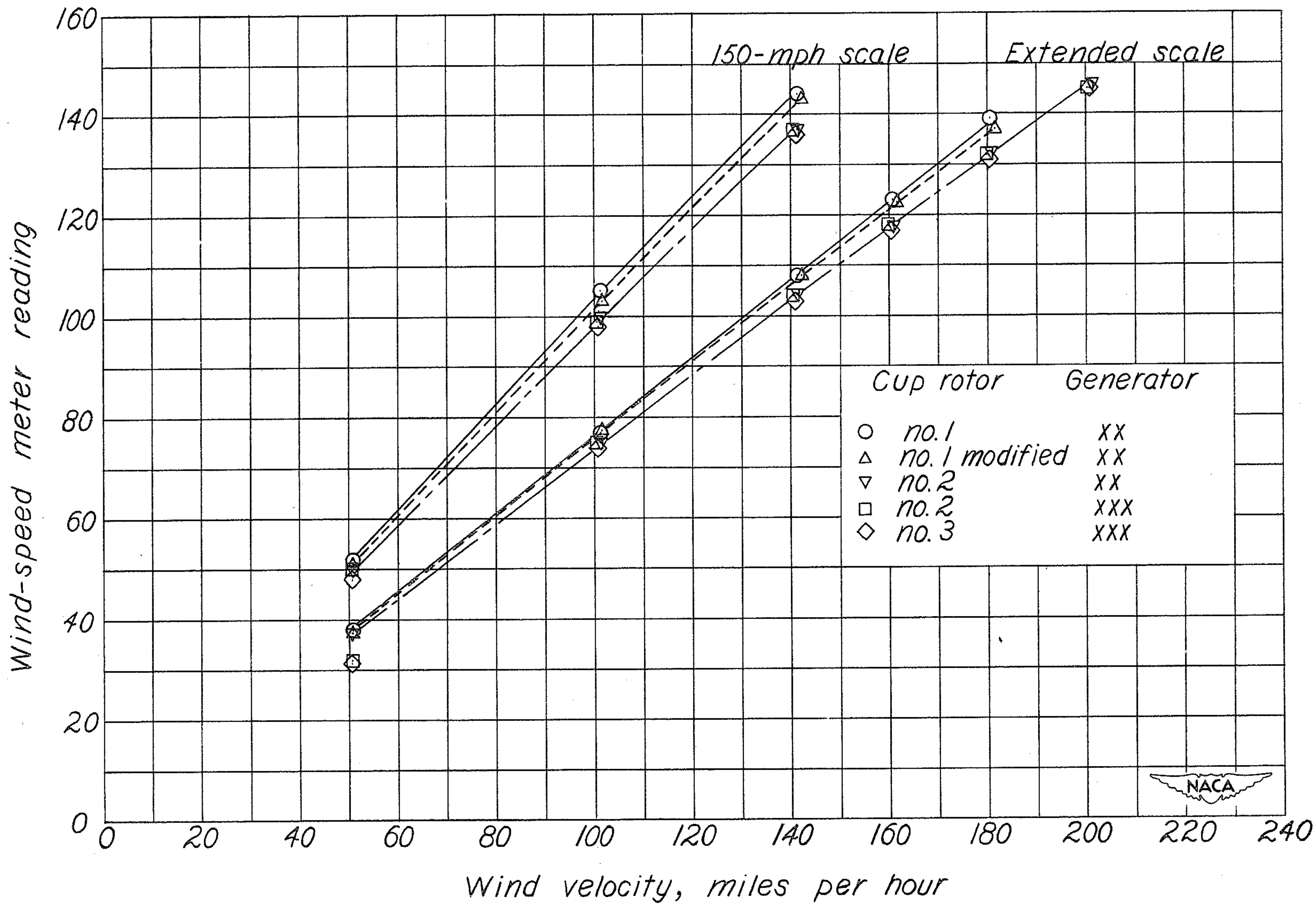

Figure 8.- Variation of the wind-speed meter reading with wind velocity for various redesigned cup rotors and generators.

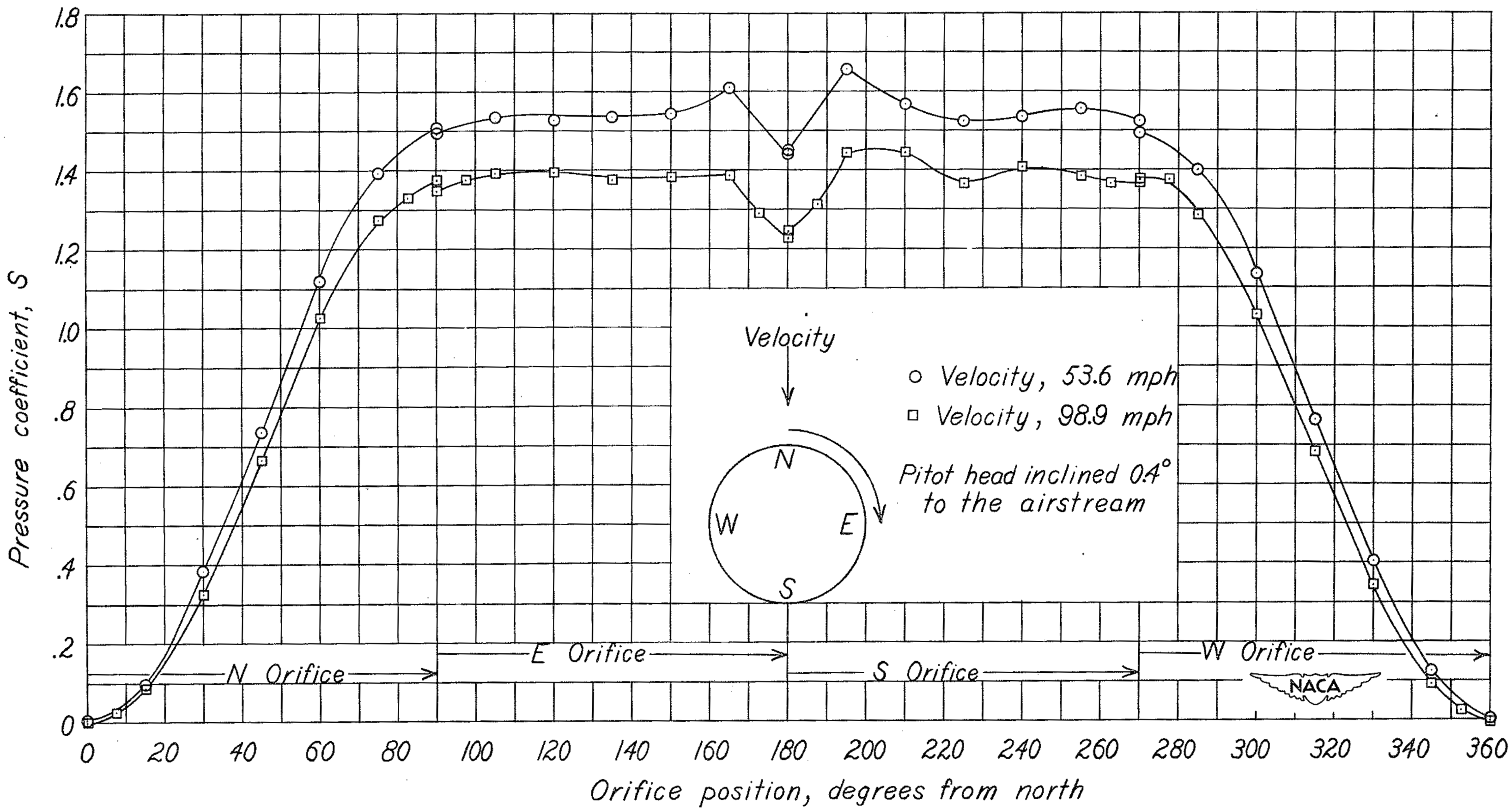

Figure 9.- Pressure coefficients at the four orifices in the disk-shaped pitot head at various positions obtained by rotating the head 90° clockwise in wind velocities of 53.6 and 98.9 miles per hour.

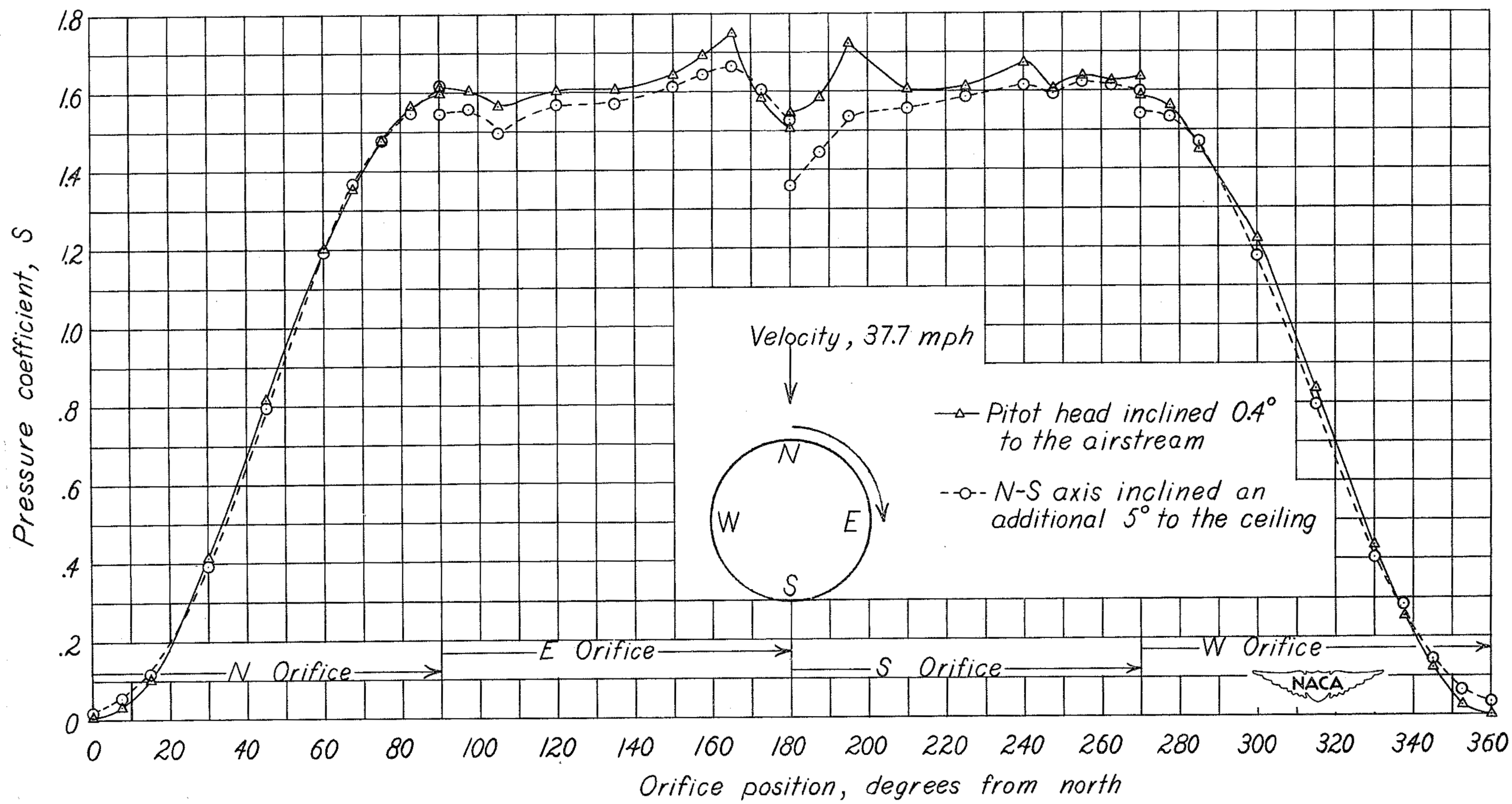

Figure 10.- Effect of inclining the disk-shaped pitot head 5° on the pressure coefficients at the four orifices at various positions obtained by rotating the head 90° clockwise in a wind velocity of 37.7 miles per hour.

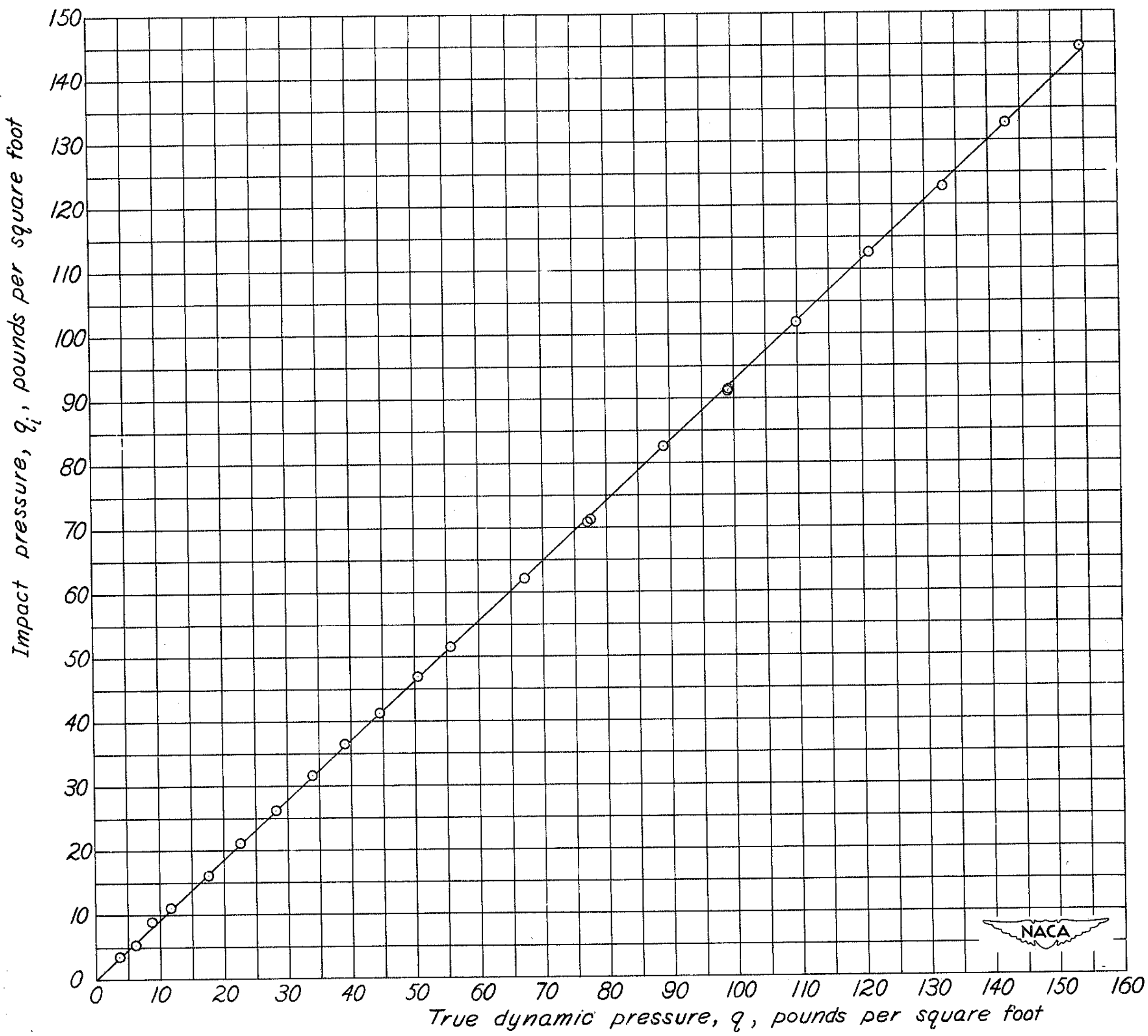

Figure 11.- Variation of the impact pressure indicated by the pitot-static tube mounted on a vane with the true dynamic pressure of the air stream.